The Effects of pH on the Kinetics of the Follow-up Reaction of Dopamine o-quinone

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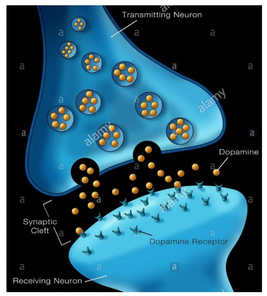
Introduction

What is Dopamine?

- Neurotransmitter that is part of the catecholamine and phenethylamine families
- Essential role in the function of reward-motivated behavior
- Various diseases and mental disorders arise from the deficiency of dopamine [1], such as:
  - depression
  - Parkinson's disease
  - Schizophrenia



Background

For this experiment we used electrochemical methods to detect the pH threshold at which cyclization of dopamine o-quinone occurs and the relationship between pH and the rate of cyclization.

1960's - Catecholamine Oxidation Pathways

- Experiments were carried out to determine the oxidation pathways of catecholamines [2]
- Cyclic voltammetry was partly used to determine these pathways but due to it being a new technique, interpretation of the data was not completely understood [2]

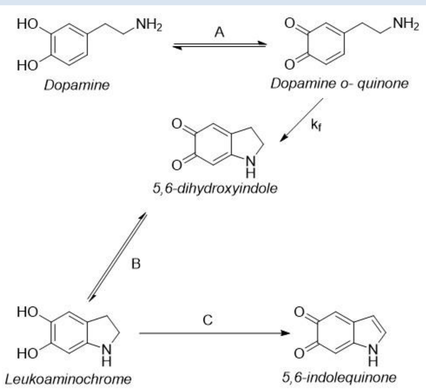
1970's - Detection of Dopamine In Vivo

- Studies carried out to measure the release and uptake of dopamine in mice, in vivo and in real-time [3]
- Use of carbon fiber microelectrodes in mice brains to determine dopamine concentrations and oxidation processes in the presence of interfering molecules [3]

Recent Studies

- The detection of dopamine has been difficult in the presence of ascorbic acid due to oxidation of both compounds occurring simultaneously. [4]
- New electrodes in development to be able to selectively detect dopamine in the presence of interfering species. [4]

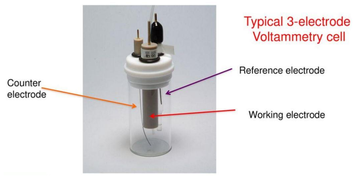
Dopamine Redox Pathway



- **A** is the electrochemical oxidation/reduction
- **k_f** is the rate constant of the follow-up reaction
- **B** is the electrochemical redox of the product
- **C** is the reaction that results in neuromelanin formation

Methods

1. Electrode and solution preparation

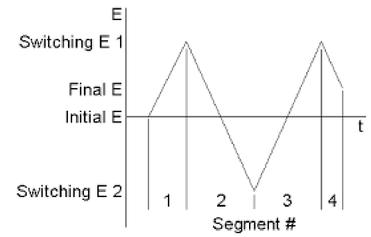


- Gold working electrode
- Platinum counter electrode
- Ag/AgCl in 1 M AgCl reference electrode.

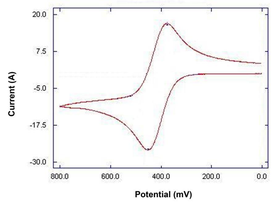
- 2 mg/ml Dopamine solution was prepared in water.
- Background electrolyte used was McIlvaine buffer, pH was adjusted with HCl and NaOH.
- The buffer containing 0.5 ml dopamine solution was deoxygenated under nitrogen for 10 minutes before measurements.

2. Cyclic Voltammetry (CV)

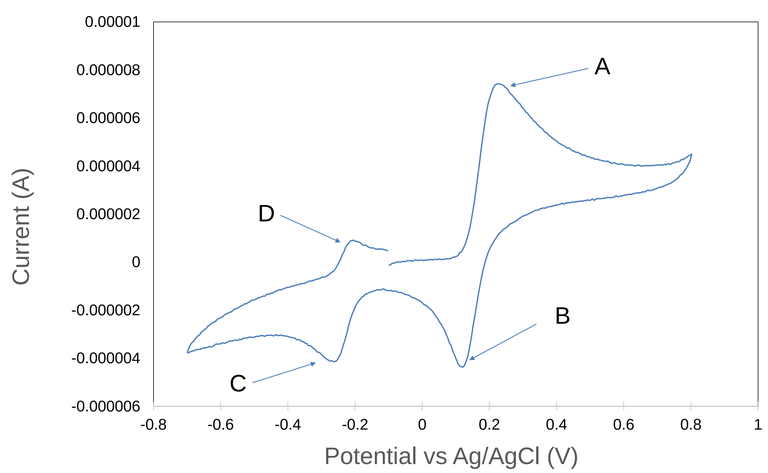
- Cyclic voltammetry (CV) measures the current resulting from the electron transfer process in the redox reaction of dopamine.
- Peak heights are proportional to the concentration of compounds in solution.
- A low scan rate was used for these CVs, as the follow up chemical reaction needs time to occur.



- A potential is applied linearly from an initial value to the first switching value.
- The potential then reverses into the opposite direction, applied with the same rate to the second switching value.
- Such potential pattern makes up a full CV cycle.

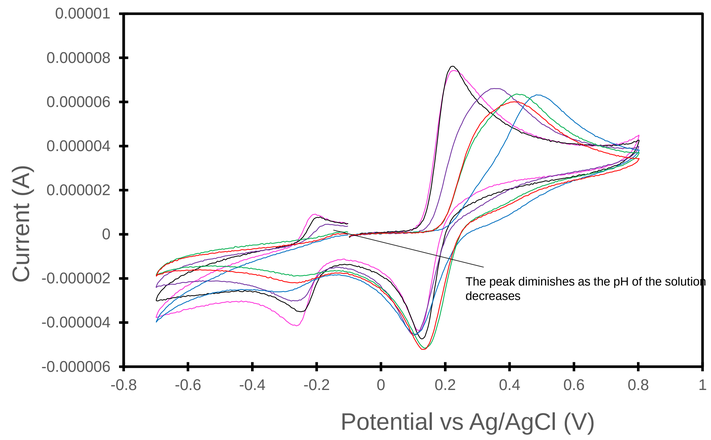


Results and discussions



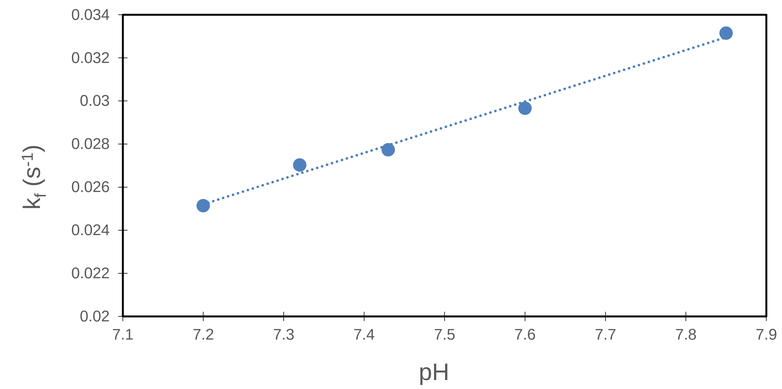
- Potential was cycled from -0.7 V to 0.8 V in the positive direction, the initial and final potentials are both -0.1 V.
- Peaks A and B represent the redox couple dopamine and dopamine-o-quinone.
- Peaks C and D represent the redox couple leukodopaminochrome and dopaminochrome.

Chemical Reaction pH Threshold



- Initial CV measurement was taken at pH = 7.04, then in decreasing pH until the second (lower) redox peaks no longer showed up.
- The second redox peaks completely diminished at pH = 5.60, indicating that this was the pH threshold for the follow up chemical reaction.

pH and Rate of Cyclization Relationship



- Linear relationship observed for the rate of cyclization as a function of pH
- Greatest rate of cyclization occurred at pH 7.8

$$y = -10.224x^3 + 26.27x^2 - 23.56x + 7.5034$$

- Each CV for each pH utilized the equation above to find k_f

Conclusions

- The pH threshold of the follow up chemical reaction was determined to be 5.60
- The kinetic rate constant was found to be linearly proportional to the pH of the electrolyte in the pH range 7.2 to 7.85.

Future Work

- Explore behavior of the follow up reaction of dopamine in basic pH ranges.
- Determine in detail the composition of the second redox couple.

Acknowledgements

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References

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[2] Adams, R. N.; Piekarski, S.; Tatawawadi, S. V.; Hawley, M. D. *J. Am. Chem. Soc.* 1967, 89:2, 447-450
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[4] Bilewicz, R.; Olszyna, A. R.; Biesiada, K.; Chmurski, K.; Majewska, U. E. Electroanalysis 18, 2006, No. 15, 1463 – 1470